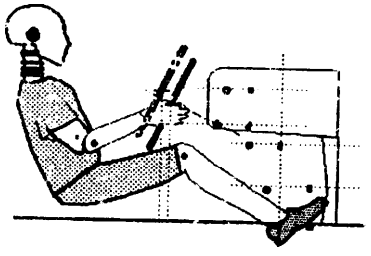
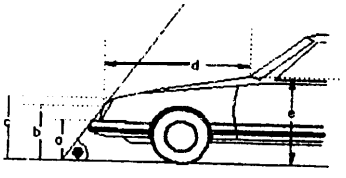
VEHICLE RESEARCH AND TEST CENTER



SINGLE-UNIT TRUCK AND BUS ABS PERFORMANCE TESTING BRAKING-IN-A-CURVE ADDENDUM EVENT REPORT



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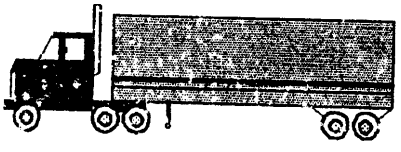

SINGLE-UNIT TRUCK AND BUS ABS PERFORMANCE TESTING BRAKING-IN-A-CURVE ADDENDUM

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1.0 INTRODUCTION

1.1 - Focus of the Study

As indicated in the March 10, 1995, final rule to require antilock braking systems (ABS) on all commercial vehicles, NHTSA (National Highway Traffic Safety Administration) conducted extensive testing on tractors in support of implementing the braking-in-a-curve test to require adequate stability and control during braking. NHTSA indicated that it would not be appropriate at that time to require dynamic test requirements for other types of hydraulic or air-braked heavy vehicles since only a small amount of testing by NHTSA on these type vehicles had been conducted at the time of the final rule. NHTSA also indicated that it anticipated conducting additional testing on these vehicles and would consider the later implementation of dynamic test requirements for these vehicles to supplement the equipment requirements.

Testing was conducted in 1996 and 1997, at NHTSA's Vehicle Research and Test Center (VRTC), on two hydraulic-braked buses and five air-braked straight trucks, all equipped with ABS, to determine if the braking-in-a-curve performance test for tractors could also be applied to single-unit vehicles. The vehicles were leased from four suppliers for the purposes of conducting these tests. The vehicles were subjected to the road test requirements in the respective Federal Motor Vehicle Safety Standards (FMVSS), either No. 105 or No. 121, that are in effect on March 1, 1999, and March 1, 1998, respectively, with one exception. The exception was that the braking-in-a-curve ABS performance tests, which are not currently included in FMVSS Nos. 105 or 121 for straight trucks and buses, were included in this test program. The results of the testing for the original seven units were detailed in an NHTSA Final Report titled, "Single Unit Truck and Bus ABS Braking-In-A-Curve Performance Testing."[1]

[1] Hoover, R. L., Howe, J. G., Flick, M. A., "Single Unit Truck and Bus ABS Braking-In-A-Curve Performance Testing," NHTSA Final Report DOT HS 808 941, February 1999.

Two additional straight trucks have been tested in 1998 and 1999 since the above report was initiated: a Navistar Model 4900 with hydraulic brakes and a Ford HN80 with air brakes. This document is an addendum to the original report. It details the results of the testing with these two vehicles.

1.2 - Overview of the Report

This document is an addendum to "Single Unit Truck and Bus ABS Braking-In-A-Curve Performance Testing." It contains ten sections that describe the various aspects of the brake-in-a-curve test program as it relates to these two vehicles. Interested parties are encouraged to read the original report for more details. Section 2.0 contains background material with a primary focus being a summary of the testing results from the original report. A description of the two additional straight trucks tested comprises section 3.0. The instrumentation installed on each of these vehicles is described in section 4.0. A description of the brake-in-a-curve test area is listed in section 5.0. Section 6.0 covers the center of gravity (CG) heights and load frame apparatus. The general sequence-of-test schedules for each FMVSS No. 105 and No. 121 standard are listed in section 7.0. Test results are given in section 8.0. Section 9.0 provides a summary of the results from the two additional straight trucks. Section 10.0, Appendices, contains individual vehicle data synopses, Roller Dynamometer effectiveness test results, vehicle information sheets, and pictures of the test vehicles and brake components.

2.0 BACKGROUND

FMVSS No's 105, 121, and 135 have the purpose of insuring safe braking performance under normal and emergency conditions. FMVSS No. 105 applies to hydraulic and electric brake systems, FMVSS No. 121 applies to air brake systems, and FMVSS No. 135 applies to light vehicle hydraulic brake systems. These standards have test procedures for various aspects of the brake systems. The road tests for FMVSS Nos. 105 and 121 are briefly described in the background section of the original report "Single Unit Truck and Bus ABS Braking-In-A-Curve Performance Testing." The following paragraphs give a brief summary of the results from the original report.

Testing was conducted in 1996 and 1997 on two hydraulic braked buses and five air braked straight trucks, all equipped with ABS, to determine if the braking-in-a-curve performance test in FMVSS No. 121 for tractors could also be applied to single-unit vehicles. The vehicles were subjected to the road test requirements in the respective Federal Motor Vehicle Safety Standards (FMVSS), either No. 105 or No. 121, plus the braking-in-a-curve ABS performance tests, which are not currently included in FMVSS Nos. 105 or 121 for straight trucks and buses.

Six of the seven vehicles tested would comply with the performance requirements currently in effect for tractors by staying in the lane in at least three out of four consecutive stops, when subjected to a full treadle or pedal brake application, at 75 percent of the maximum drive-through speed (minimum required brake-through speed). In fact, these six vehicles remained in the lane during all four stops at the minimum brake-through speed and all had a significant margin of compliance.

The seventh vehicle, the Navistar 4x2 with a 148 inch wheelbase, met the minimum requirement for the loaded condition. Here, it achieved a maximum brake-through speed of 78 percent of the maximum drive-through speed, but did not pass the empty condition, where the maximum brake-through speed was only 61 percent of the maximum drive-through speed. It should be noted that this vehicle had a drive axle with a gross axle weight rating of 30,000 pounds. FMVSS No. 121 exempts vehicles that have an axle with a weight rating of 29,000 pounds or more from having to comply with the Standard.

In general, when determining the maximum drive-through speed, the test vehicle front end tended to plough out at the limit, departing the lane on the outside of the curve. When determining the maximum brake-through speed, the rear end of the test vehicle would tend to "walk out" at the limit, also departing the lane on the outside of the curve.

NHTSA's Office of Safety Performance Standards has proposed that an upgrade to FMVSS No. 105 include a 150 pounds-force brake pedal force application within 0.2 seconds from the point of application of the brake pedal. This proposal was made after the hydraulic braked vehicles in the initial study were tested and returned to the manufacturers. This proposed application is higher than the 60 to 100 pounds-force that occurred during the initial testing. Full ABS cycling was achieved at these lower brake pedal forces. Brake pedal force application data was not available for the hydraulic brake vehicle testing described in this Addendum. Therefore, this Addendum cannot provide any information about this issue.

In considering "apply times" for the pneumatic braked straight trucks, all of the test vehicles that had the appropriate instrumentation surpassed the FMVSS No. 121 required minimum control pressure of 85 psi (at the treadle valve) in less than 0.2 seconds as specified for tractors. This application time appears to be repeatable.

The results of testing showed that the braking-in-a-curve test is practicable, repeatable, and safe to perform for single unit vehicles.

3.0 TEST VEHICLES

Vehicle specifications for the buses and the straight trucks tested in the original study are given in Table 3.1. The brake type, vehicle configuration, wheelbase, Gross Axle Weight Ratings (GAWR), and Gross Vehicle Weight Rating (GVWR) are listed. A more detailed description of these test vehicles is given in the original report.

Table 3.1: Vehicle Specifications for VRTC Brake-In-A-Curve Tests - 1996-1997

Vehicle Manufacturer	GMC	Freight-liner	Freight-liner	Peterbilt	Navistar	Navistar	Navistar
Vehicle ID Code	A	B	C	D	E	F	G
Vehicle Type	Bus	Bus	Straight Truck	Straight Truck	Straight Truck	Straight Truck	Straight Truck
Brake Type	Hydraulic	Hydraulic	Air	Air	Air	Air	Air
Vehicle Configuration	4x2	4x2	6x4	6x4	6x4	4x2	4x2
Wheelbase (in)	193	252	180	311	238	152	148
GAWR front (lb)	8100	7560	12000	20000	15000	14600	20000
GAWR rear (lb)	19000	17940	40000	40000	46000	21000	30000
GVWR total (lb)	27100	25500	52000	60000	61000	35600	50000

The specifications for the two additional test units for this study are given in Table 3.2. Unit H is a Ford HN80 Louisville straight truck with air brakes, while unit I is a Navistar Model 4900 with hydraulic brakes. This is the only hydraulic-braked straight truck tested in this program. It also has the shortest wheelbase of all the vehicles tested (140 inches). The axles on unit I actually have larger GAWR than those listed. The values listed in Table 3.2 correspond to the braking capacity that the vehicle was designed for.

Table 3.2: Vehicle Specifications for VRTC Brake-In-A-Curve Tests - 1998-1999

Vehicle Manufacturer	Ford	Navistar
Vehicle ID Code	H	I
Vehicle Type	Straight Truck	Straight Truck
Brake Type	Air	Hydraulic
Vehicle Configuration	4x2	4x2
Wheelbase (in)	148	140
GAWR front (lb)	12,000	8,000
GAWR rear (lb)	23,000	15,500
GVWR total (lb)	35,000	23,500

Unit H has air brakes and was therefore subjected to the FMVSS No. 121 test series. This series and additional tests were performed at the VRTC with the exception of the initial burnish which was performed prior to arrival at VRTC. Unit I has hydraulic brakes and therefore was subjected to the FMVSS No. 105 test series. The majority of this testing was performed by Navistar prior to the arrival of the vehicle at VRTC. The brake-in-a-curve portion of the testing was performed at the VRTC. Navistar provided the driver and instrumentation. The vehicle speeds on the drive-through and brake-through runs were monitored by VRTC staff. Lane maintainability was also monitored. For both units, the brakes were in good condition.

4.0 INSTRUMENTATION

Unit H was instrumented with a VRTC data acquisition system similar to those used in the original study. The data acquisition system's main function was to log key physical parameters of the driver input, vehicle response, and braking performance, all with respect to elapsed time. Unit I was instrumented and the data collected by Navistar. Only initial speed and stopping distance data were made available to NHTSA.

4.1 - Data Acquisition Overview

The major components of the VRTC data system were: a laptop PC with two AT-type expansion slots, an internally mounted digitizer, a signal conditioning breakout box, various cables, parameter measurement transducers, and three monitors for the driver, including a Labeco Performance. Monitor, and a Fluke Thermocouple Monitor.

The laptop PC controlled the acquisition of the data. The system functions were manipulated through "DACS" data acquisition routines, written at VRTC. Inside the laptop was an Analog Devices RTI-815, 12-bit digitizer. The digitizer was configured to acquire analog data from up to twenty channels. Data were collected at a digitizing rate of 100 samples per second. The original report provides further information about the VRTC instrumentation package.

4.2 - Transducer Information

Transducers were used to measure vehicle speed, brake line pressures, control pressure (on pneumatic braked vehicles) and pedal force (on hydraulic braked vehicles), deceleration, stopping distance, and brake temperatures, during the testing of each vehicle. A complete list of the data channels measured for each vehicle is given in Table 4.1. A description of all the transducers used on VRTC instrumented vehicles is given in the original report.

Table 4.1: Data Acquisition Channel List for FMVSS No. 105 & FMVSS No. 121 VRTC Brake-In-A-Curve Tests - 1998-1999

Veh. ID Code	H	I	
Manufacturer	Ford	Navistar	
Type	4x2	4x2	
Wheelbase (in)	148	140	
Number of Data Channels	10	NA	
Sample Rate (Hz)	100	NA	
Channel Name			Description
EVENT	X	NA	brake event
VHSPD	X	NA	vehicle speed
DECEL	X	NA	deceleration
PDFRCE		NA	pedal force (105 only)
PDTRVL		NA	pedal travel (105 only)
CTLPRS	X	NA	control pressure (121)
1CHPS		NA	LF brake pressure (121 only)
2CHPS	X	NA	RF brake pressure (121 only)
3CHPS		NA	LR brake pressure (121 only)
4CHPS	X	NA	RR brake pressure (121 only)
1WHSPD	X	NA	left wheel speed-axle 1
2WHSPD	X	NA	right wheel speed-axle 1
3WHSPD	X	NA	left wheel speed-axle 2
4WHSPD	X	NA	right wheel speed-axle 2
1TEMP	X	NA	brake temperature-axle 1L
2TEMP	X	NA	brake temperature-axle 1 R
3TEMP	X	NA	brake temperature-axle2L
4TEMP	X	NA	brake temperature-axle2R

Notes:

1) Unit I was instrumented by Navistar and a channel list is Not Available (NA).
2) Unit I was only tested for the brake-in-a-curve sequence at VRTC.

5.0 BRAKING-IN-A-CURVE TEST AREA

The braking-in-a-curve tests were conducted on a low coefficient of friction surface on the Transportation Research Center proving grounds in East Liberty, Ohio. The test area was located inside the fifty acre asphalt rectangle, the Vehicle Dynamics Area (VDA), which provided a safety run-off area if the test vehicle needed to abort a braking maneuver. The coefficient of friction for most of the VDA was a relatively high 0.9. This provided excellent traction for accelerating to test speed. The layout of the VDA provides a relatively quick means of repeating test cycles with minimal milage accumulation on the tires and brakes.

Located on the southern section of the VDA was the Braking-In-A-Curve area. This section of the VDA was coated with Jennite (a driveway sealer) and wetted with water to provide the reduced (0.5 nominal peak) coefficient of friction surface for the brake tests. A curved, 12-foot-wide lane was laid out (12 feet between the inside edges of painted eight-inch squares), with the center of the lane having a 500-foot radius of curvature, and an arc length of over 500-feet. The squares were painted on radials corresponding to every 20 foot of centerline arc length. Traffic cones were placed on each painted square, maintaining twelve feet of spacing between the base of the sides facing the lane. This provided a clear lane reference without solidly painting a lane line that would cause a variance in the surface's coefficient of friction. Further details are given in the original report.

An excerpt from the TRC periodic report of "Monitored Test Surfaces" is given in Table 5.1. A partial history of the surface friction coefficients for 1996 - 1997 and 1998-1999 is shown. It includes coefficients for the wet Jennite pad (#8) used for vehicle stability brake-in-a-curve tests and for the dry concrete skid pad (#3) used to run high speed braking maneuvers for the other test procedures. The peak coefficient of friction (PFC) of the surface during the time of the testing ranged from 0.36 to 0.39. Earlier testing had a range of 0.34 to 0.39.

Table 5.1: "Monitored Test Surfaces" Information for 1996-1997 and 1998-1999

Location	Skid Pad-Lane 3	VDA
Pad#	3	8
Pavement	Polished Concrete	Jennite over Asphalt
Type of Tests Run on Surface	High Speed Braking Maneuvers	Brake-In-A-Curve Tests
Condition as Tested	Dry	Wet
Peak/Slide Coefficients	Peak Brake Coefficient / Slide Number Coefficient	Peak Brake Coefficient
Nominal Coefficient #'s	90 / 75	30
Date	Peak mu / Slide mu	Peak mu
06/28/96*	87 / 80	36
08/21/96*	90 / 78	37
10/28/96*	95 / 78	34
12/04/96*	96 / 79	38
01/07/97*	94 / 81	37
04/01/97*	96 / 81	39
05/20/97*	87 / 81	37
01/05/98	94/79	39
04/08/98	91/84	na**
05/01/98	90/na	na**
04/07/99	91/82	37
04/23/99	96/82	36

Peak Brake Coefficient measured per ASTM E1337 with an ASTM E1336 standard tire.
Slide Number Coefficient measured per ASTM E274 with an ASTM E501 standard tire.
* - Original Study Values
** - Another Jennite surface (pad 9) located near pad 8 had skid values in the low 30's, pad 8 was slightly higher than pad 9 near this time frame

6.0 VEHICLE LOADING AND LOAD FRAMES

To simulate the unloaded condition of completed vehicles, a load frame was installed on the chassis cab straight trucks for the performance tests conducted in the unloaded condition. The Ford HN80 (unit H) was fitted with a 2600 pound load frame by VRTC. Dimensional characteristics for the VRTC load frame are given in the original report. Navistar supplied an extra high load frame (~3,560 pounds) for the 140" (unit I) wheelbase 4x2 truck. The "unit I" truck was tested in a high CG mode. The load frames, which are used to secure ballast to the vehicles for testing in the loaded condition, include an integral roll bar to protect the test driver in the event of rollover during the tests.

To achieve a fully laden condition for the straight trucks, ballast was added (See Table 6.1). This condition was accomplished by adding steel and/or concrete weights to the load frame such that the total weight of the vehicle was equal to the GVWR (gross vehicle weight rating) and the axle loads were in proportion with the front and rear GAWRs (gross axle weight ratings).

Table 6.1: Ballast CG Height Calculations for FMVSS No. 121

Brake-In-A-Curve Straight Truck Tests

Manufacturer	Ford	Navistar
Vehicle ID Code	H	I
Axle Configuration	4x2	4x2
GVWR Configuration (lb)	35,000	23,500
Wheelbase	148 in	140 in
Bare chassis-cab CG height (CG height above ground, without the load frame installed)	estimate not available	40 in. Navistar Estimate
Load Frame weight (lb)	2,600	3,560
Load Frame vertical CG height above truck; frame rails	17.1 in	height not available
Weight Lightly Loaded includes load frame (lb)	14,040	14,570
Lightly Loaded vehicle CG height (CG height above ground after installing the load frame)	estimate not available	40 in. Navistar calculated
Ballast Weight (lb)	20,800	8,660
Ballast CG height above truck frame rails	26.5 in	height not available
Combined Load Frame and Ballast Weight (lb)	23,400	12,220
Combined Load Frame and Ballast CG height above truck frame rails	25.5 in	≈50 in
Weight Laden (lb)	34,840	23,230
Laden Vehicle estimated vertical CG height above ground	estimate not available	65 in. Navistar Calculated

7.0 TEST PROCEDURE AND TEST SEQUENCE

7.1 - General Test Procedures and Test Sequence

Prior to testing, for safety reasons, a suitable load frame with an integral safety rollbar was installed on the chassis frame vehicles (see section 6.0 - Vehicle Loading). Instrumentation was installed (see section 4.0 - Instrumentation). Before the vehicle was weighed, and again before each major step in the test sequence, all fuel tanks and fluid reservoirs were filled to normal capacity. This maximized test repeatability.

The driver was briefed before each test sequence. The sequence of tests performed under each standard (the proposed braking-in-a-curve portion of FMVSS No. 105 and the road test sequence for FMVSS 'No. 121) are listed on the following page. One deviation from the standard test procedures was that after the Initial Burnish, both of the vehicles were tested for brake effectiveness at slow speed on a Hans Herman BM Roller Dynamometer (see Appendix No. 3 for the Roller Dynamometer description and brake force plots). FMVSS No. 105 also specifies a First Effectiveness test that was not performed for this study because the vehicle tested to this standard was received with the Initial Burnish already performed.

Detailed procedures for each test are contained in the respective FMVSS and a brief summary is given in the original report. A detailed explanation of the braking-in-a-curve tests are contained in the next section. As noted earlier, only the braking-in-a-curve tests were performed at VRTC for the Navistar (unit I).

FMVSS No. 105 -Test Sequence

1. ***Proposed*** Stability and Control, Brake-in-a-curve Loaded - at GVWR
2. ***Proposed*** Stability and Control, Brake-in-a-curve Empty - at LLVW

FMVSS NO. 121 - Test Sequence

1. Burnish
2. ***Proposed*** Stability and Control, Brake-in-a-curve Loaded - at GVWR
3. ***Proposed*** Stability and Control, Brake-in-a-curve Empty - at LLVW
4. Manual Brake Adjustment Allowed
5. Service brake stopping distance test at GVWR.
6. Emergency brake stopping distance test for single unit truck only at GVWR.
   - Primary system failure.
   - Secondary system failure.
7. Manual Brake Adjustment Allowed
8. Service brake stopping distance test at LLVW.
9. Emergency brake stopping distance test at LLVW.
   - Primary system failure.
   - Secondary system failure.

7.2 - Stability and Control, Braking-In-A-Curve Test Procedure

The braking-in-a-curve tests were conducted by finding the maximum drive-through speed, making four stops at 75 percent of the maximum drive-through speed (minimum required brake-through speed), as is specified for truck tractors, and then also determining the maximum brake-through speed. Maximum drive-through speed is defined as the fastest constant speed that a vehicle can be driven through at least 200 feet of curve arc length without departing the lane on a 500-foot radius curve with a 0.5 peak friction coefficient surface, with the driver making steering corrections as necessary. Maximum brake-through speed is defined as the fastest speed at which a full brake application can be made while the vehicle is in the curve without the vehicle departing the lane, with the driver making steering corrections as necessary.

In conducting; the tests, the driver was instructed to begin the test in the center of the lane and to steer as necessary to keep the vehicle within the lane. If any cones were hit, the vehicle was considered to have gone out of the lane. The maximum drive-through speed was determined by making passes through the lane at a constant speed and increasing or decreasing the speed slightly on each successive pass to determine the maximum speed at which the vehicle would remain within the lane. Once this speed was determined, two or three additional passes were made to verify that the speed determined was the maximum speed at which the vehicle would remain in the lane. Next, four stops were made at the minimum required brake-through speed (75 percent maximum drive-through). The vehicle must stay within the lane on at least three of four consecutive tests. If a unit failed this requirement, the speed was lowered in one mph increments to a speed where three of the four stops resulted with the vehicle staying in the lane. Finally, the maximum brake-through speed was determined by making successive stops increasing the speed appropriately to find the maximum speed at which the vehicle would remain in the lane. For these stops, the brake was applied as rapidly as possible to a full pressure application or full travel condition and held until the end of the stop.

As currently specified in FMVSS No. 121 for truck-tractors, the required minimum brake-through speed to be used in the braking-in-a-curve test is either 75 percent of the drive-through speed or 30 mph, whichever is lower. Calculated from these requirements, in order for a 30 mph brake-through speed to be used, the drive-through speed would have to be 40 mph or greater. The straight trucks tested had maximum drive-through speeds ranging between 33 and 35 mph, therefore, the 75 percent of drive-through speed, rather than the 30 mph speed, applied to each of these vehicles.

8.0 TEST RESULTS

8.1 - Braking-in-a-Curve Test Results

The Braking-in-a-Curve test results for the two test vehicles are summarized in Table 8.1. The vehicle identification code (H-I for vehicle, 1 or 2 for loading condition), vehicle manufacturer, type of vehicle, wheelbase, loading condition, maximum drive-through speed, required minimum brake-through speed, maximum brake-through speed, and maximum brake-through/maximum drive-through ratio are tabulated. The maximum drive-through speeds are similar to those found in the original study. The maximum brake-through/maximum drive-through ratios were much higher than the 75% minimum requirement. Unit H had a ratio of 100% in the empty condition, while unit I had a 103% ratio (maximum brake-through greater than the maximum drive-through) in the loaded condition.

TABLE 8.1: VRTC Brake-In-A-Curve Test Results for FMVSS No. 105 and FMVSS No. 121 - 1998-1999

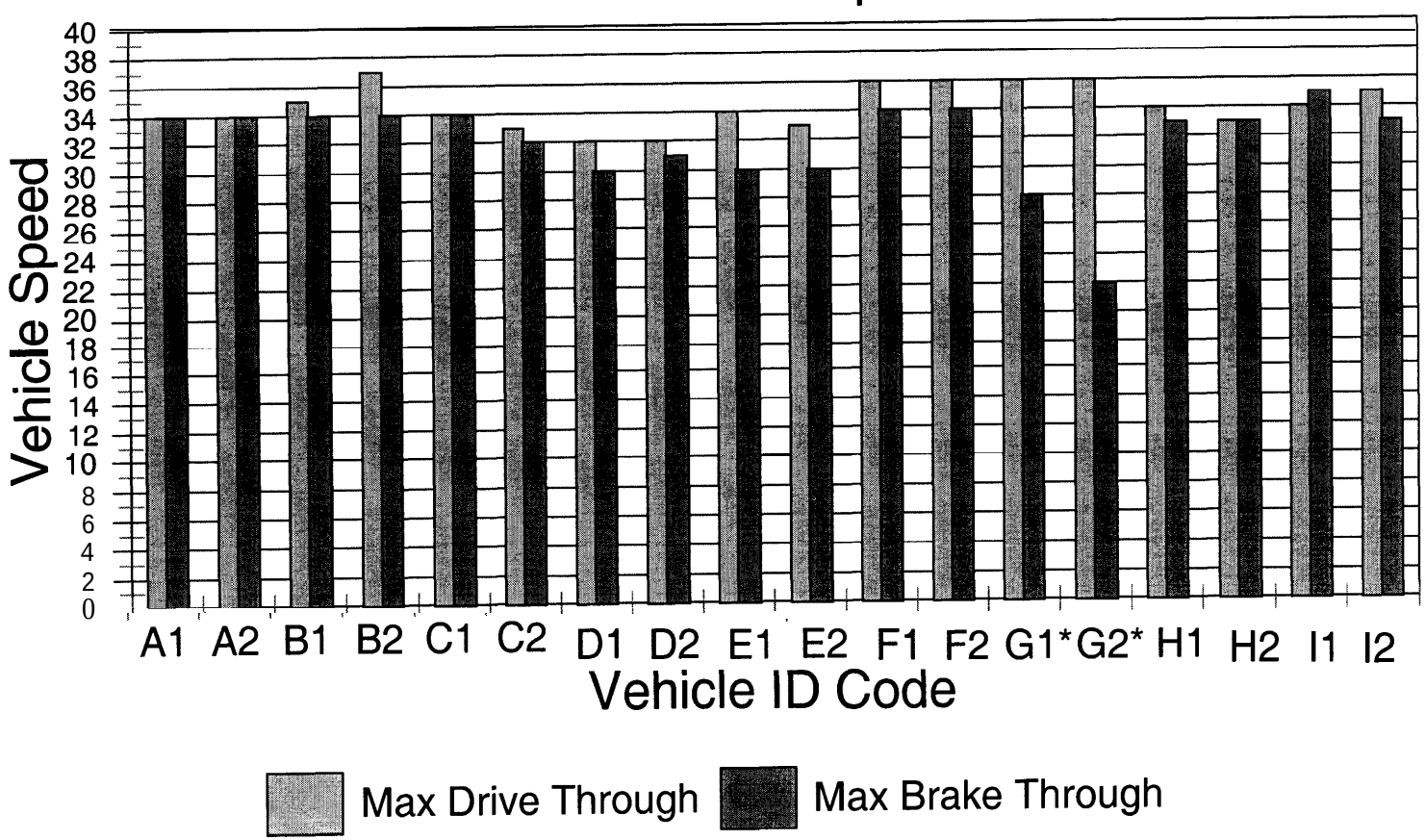
Vehicle ID Code	Manufacturer	Type	Wheel-base (in)	Test Condition	Max Drive-Through (mph)	Required Minimum Brake-Through (mph)	Max Brake-Through (mph)	Max Brake-Through/ Max Drive-Through % (75% Min.)
H1	Ford	4 x 2	148	loaded	34	26	33	97
H2	Ford	4 x 2	148	empty	33	25	33	100
I1	Navistar	4 x 2	140	loaded	34	26	35	103
I2	Navistar	4 x 2	140	empty	35	26	33	94

Notes: Required Minimum Brake-Through speeds listed are 75 percent of the Maximum Drive-Through speed.
Vehicle ID Code suffix "1" indicates the vehicle tested in the GVWR loaded condition.
Vehicle ID Code suffix "2" indicates the vehicle tested in the empty condition.

The maximum drive-through and maximum brake-through speeds are plotted in Figure 8.1 for each vehicle in both the original and current study. The maximum brake-through/drive-through ratio is plotted in Figure 8.2. Both of these figures show that units A-F (original study) have brake-through/drive-through ratios that are well above the 75 percent minimum requirement. The seventh vehicle, unit G (original study) - the Navistar 4x2 - 148 inch wheelbase, met the minimum requirement for the loaded condition (78 percent), but did not pass the empty condition (61 percent). It should be noted that this vehicle had a drive axle with a gross axle weight rating of 30,000 pounds, which was greater than the 29,000 pound maximum GAWR specified in FMVSS No. 121 section S3(b), and therefore is not required to pass FMVSS No. 121 test procedures. However, vehicle manufacturers using axles with the higher weight ratings can opt to certify to this standard. As stated previously, units H and I (current study) have brake-through/drive-through ratios that are also well above the 75 percent minimum requirement.

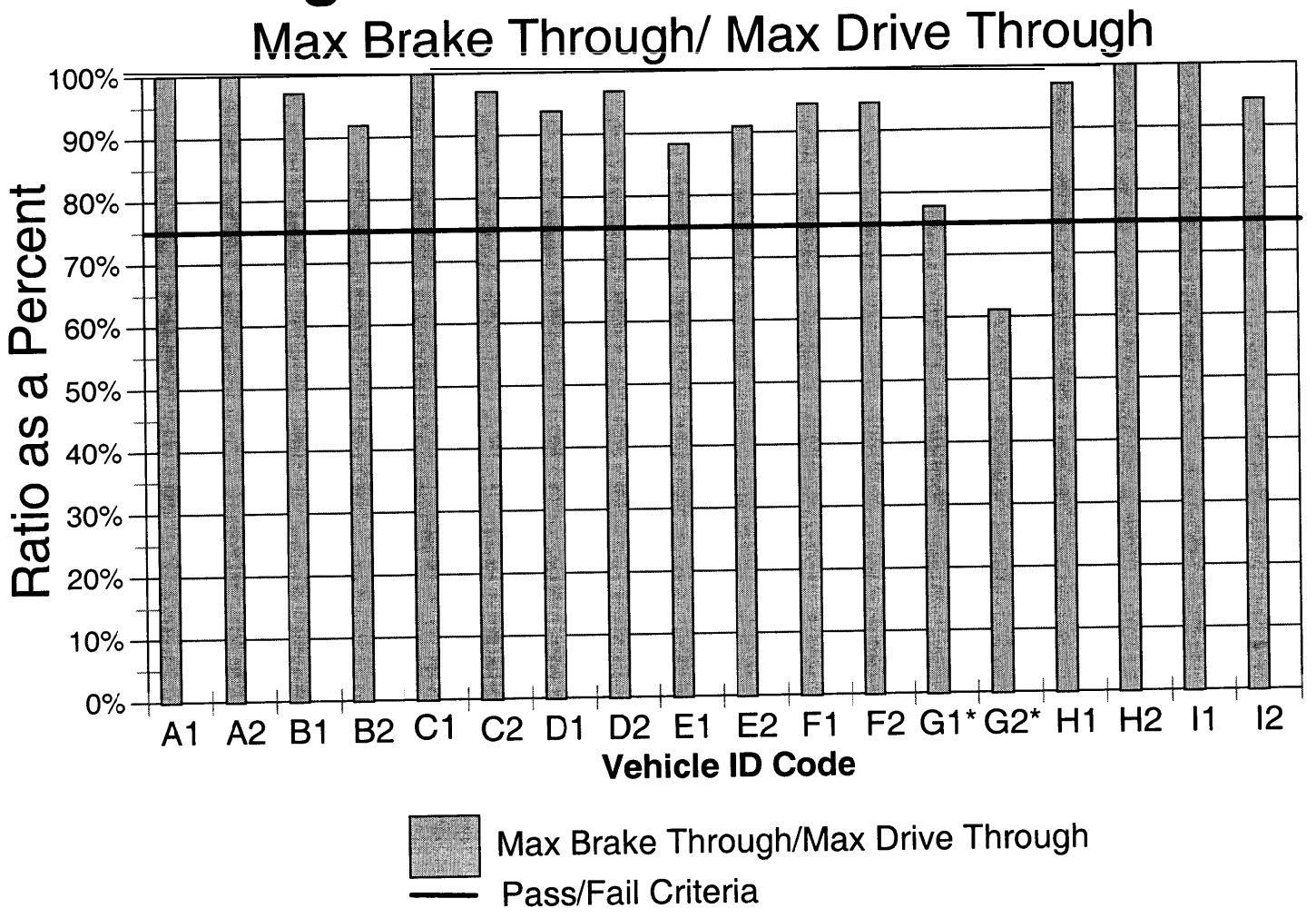
For safety reasons, the maximum test speed permitted by the test procedure was 40 mph. None of the vehicles were able to achieve this high a value. When determining the maximum drive-through speed, the test vehicle front end tended to plough at the limit, departing the lane on the outside of the curve. When determining the maximum brake-through speed, the rear end of the test vehicle would tend to “walk out” at the limit, also departing the lane on the outside of the curve. Unit I had a different behavior. The rear end would tend to slip out of the lane at the limit of performance in both the drive-through and brake-through tests. The wheelbase for unit I is less than the other vehicles and this may explain the different behavior.

Figure 8.1: Brake-in-a-Curve



* indicates that this unit has a rear axle that exceeds the 29,000 pound maximum axle rating to which FMVSS No. 121 applies

Figure 8.2: Brake-in-a-Curve



* indicates that this unit has a rear axle that exceeds the 29,000 pound maximum axle rating to which FMVSS No. 121 applies

The proposed FMVSS additions for Braking-in-a-Curve testing require that a minimum brake-through speed equal to 75 percent of the maximum drive-through speed, or 30 mph, whichever is less, be repeated four times. The vehicle must be able to maintain the lane for three of the four consecutive test runs. The eight vehicles that passed both the empty and loaded conditions (units A-F and H-I) remained in the lane during all four stops at the required minimum brake-through speed and all had a significant margin of compliance as noted by Brake-Through/Drive-Through percentages being higher than 75 percent. The other vehicle (unit G) stayed in the lane in all four of the stops at the required minimum brake-through speed in the loaded condition.

As stated in the original report, the results of testing at VRTC continue to show that the braking-in-a-curve test is practicable, repeatable, and safe to perform for single unit vehicles.

8.2 - Summary of Other FMVSS No. 121 Test Results

The Ford HN80 (unit H) had an air brake system and therefore was subject to the requirements of FMVSS No. 121. Summaries for the Service Brake and Emergency Brake Stopping Distance tests for unit H are contained in Table 8.2 Service Brake stopping distances are the lowest values from six tests. The same is true for the failed primary and failed secondary tests. The stopping distances have been corrected per SAE J299.

The Ford HN80 (unit H) had Service Brake (fully functioning systems) stopping distances that met the requirements of FMVSS No. 121. The Emergency Brake (partially failed systems) stopping distances for the failed primary and secondary reservoirs also met the FMVSS No. 121 requirements. The failed system tests resulted in longer stopping distances than those for the full system.

Table 8.2: Summary of Service Brake and Emergency Brake Stopping Distance for Ford HN80 4×2 Straight Truck

Spring Suspension, Air Brakes, 148" Wheelbase, GAWR Front 12,000, GAWR Rear 23,000

	Loaded		Empty	
	Measured Stopping Distance (ft)	Allowed Maximum (ft)	Measured Stopping Distance (ft)	Allowed Maximum (ft)
Full System - stops from 60 mph				
60 mph	273	310	182	335
Failed System - stops from 60 mph				
Primary	393	613	286	613
Secondary	527	613	375	613

9.0 SUMMARY

Testing was conducted in 1998 and 1999, at NHTSA's Vehicle Research and Test Center (VRTC), on one hydraulic-braked and one air-braked straight truck, both equipped with ABS, to determine if the braking-in-a-curve performance test currently required for truck-tractors could also be applied to single-unit vehicles. This work is in addition to the work performed for the original study which was described in the report, "Single Unit Truck and Bus ABS Braking-In-A-Curve Performance Testing." This addendum documents the results from the testing of the two additional vehicles. The vehicles were subjected to the road test requirements in the respective Federal Motor Vehicle Safety Standards (FMVSS), either No. 105 or No. 121, plus the braking-in-a-curve ABS performance tests, which are not currently included in FMVSS Nos. 105 or 121 for straight trucks and buses. The major finding from the original study was that the braking-in-a-curve test is practicable, repeatable, and safe to perform for single unit vehicles. The results of the testing for the two vehicles in this study show that this is still a true statement. The original report contains a list of ten summary items for the results from the initial testing. The results of this study do nothing to change those summary items. The following is a summary of results for the two vehicles evaluated and reported on in this addendum:

1. The test results indicate that the two vehicles tested would comply with the performance requirements currently in effect for tractors of staying in the lane in at least three out of four consecutive stops, when subjected to a full treadle or pedal brake application, at 75 percent of the maximum drive-through speed. In fact, these vehicles remained in the lane during all four stops at 75 percent of the drive-through speed and both had a significant margin of compliance.

2. In considering "apply times" for the pneumatic braked straight trucks, the Ford HN80 straight truck (unit H) surpassed the FMVSS No. 121 required minimum control pressure of 85 psi (at the treadle valve) in less than 0.2 seconds as specified for tractors. All the test vehicles in the original study with the appropriate instrumentation also passed this requirement.

3. When determining the maximum drive-through speed for all of the vehicles tested in the original study and unit H (the Ford HN80), the test vehicle front end tended to plough-out at the limit, departing the lane on the outside of the curve. When determining the maximum brake-through speed, the rear end of the test vehicle would tend to "walk out" at the limit, also departing the lane on the outside of the curve. Unit I (Navistar 4900 - 140 inch wheelbase) had a different behavior. The rear end would tend to slip out of the lane at the limit of performance in both the drive-through and brake-through tests. The wheelbase for unit I is less than the other vehicles and this may explain the slightly different behavior.

4. The Navistar 4900 (140 inch wheelbase) straight truck had a hydraulic brake system and therefore was subject to the requirements of FMVSS No. 105. These tests were conducted by the manufacturer prior to bringing the vehicle to VRTC. The data for these tests were not available.

5. The Ford HN80 straight truck had an air brake system and therefore was subject to the requirements of FMVSS No. 121. This vehicle had Service Brake (fully functioning systems) stopping distances that met the requirements of FMVSS No. 121. The Emergency Brake (partially failed systems) stopping distances for the failed primary and secondary reservoirs also met the FMVSS No. 12 1 requirements.

10.0 Appendices - Index

Key: GAWR = Gross Axle Weight Rating (for each axle)
GVWR = Gross Vehicle Weight Rating (referred to as loaded)
LLVW = Lightly Loaded Vehicle Weight (referred to as empty)
IBT = Initial Brake Temperature (just before stop was initiated)
fpsps = Feet Per Second Per Second (deceleration rate)

10.1 Appendix 1

FMVSS 121 - Ford HN80
Test Sequence

Steps 2-9 in this sequence were performed at VRTC. The brakes were burnished by the vehicle supplier prior to arrival at VRTC.

STABILITY & CONTROL TEST DATA SHEET
Brake-In-Curve Wet Jennite

Vehicle: 1996 Ford Louisville ☒ GVWR ☐ LLVW
Date 4-16-98 Driver: Lyle Observer: Dick

TEST SPECIFICATIONS:

- Check Tire Pressure
- Max. Drive-Through Speed (nearest whole mph): 34
- 75% of Max. Drive-Through Speed (nearest whole mph): 25
- Braking Runs at 30 mph or 75% Max. Drive-Through Speed: 26
- IBT 150 to 200 °F
- Clutch Depress or Transmission in Neutral
- Full Brake Application
- Vehicle Within Lane at Start
- Manually Controlled Retarder ON _____ OFF _____
  N/A ✓

stop No.	Speed (mph)	Apply Time (sec)	Approx. Dist. Out of Lane (ft)	No. Markers Hit	Comments
1	26.4	0.12	0	0	97.8 Ft.
2	26.3	0.08	0	0	90.0 Ft.
3	26.3	0.13	0	0	89.1 Ft.
4	26.1	0.11	0	0	86.0 Ft.

Ambient Temp.: 64 Wind Speed: 10-14 Direction: 224 SW

Comments Max Brake-Through 33 mph (97%)

For drive-through attempts- Front Slides out at 35 mph

STABILITY & CONTROL TEST DATA SHEET
Brake in Curve Wet Jennite

Vehicle: 1996 Ford Louisville ☐ GVWR ☒ LLVW
Date 4-17-98 Driver: Lyle Observer: Dick

TEST SPECIFICATIONS:

- Check Tire Pressure
- Max. Drive-Through Speed (nearest whole mph): 33 mph
- 75% of Max. Drive-Through Speed (nearest whole mph): 25 mph
- Braking Runs at 30 mph or 75% Max. Drive-Through Speed: 26 mph
- IBT 150 to 200 °F
- Clutch Depress or Transmission in Neutral
- Full Brake Application
- Vehicle Within Lane at Start
- Manually Controlled Retarder ON _____ OFF _____
  N/A ✓

stop No.	Speed (mph)	Apply Time (sec)	Approx. Dist. Out of Lane (ft)	No. Markers Hit	Comments
11	25.9.9	0.09.09	0 0	0 0	71.71.5 Ft.
22	26.26.2	0.14 0.14	0 0	0	77.8 Ft.
33	2626.8	0.10.0.10	0 0	0 0	82.72.7 Ft.
44	26.26.1	0.11 0.11	0 0	0	78.6 Ft.

Ambient Temp.: 38 Wind Speed: 12 Direction: 3 18 NW

Comments Max brake-through 33 mph (100%)

For drive-through attempts-Front plows out at 34 mph

SERVICE BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ☒ GVWR ☐ LLVW
Date: 4-17-98 Driver: Lyle Observer: _____

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder. ON _____ OFF _____
  N/A ✓

60 mph Service Brake Stops

stop	Application Pressure (psi)		Speed (mph)	Decel (ft/sec^2)	stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	105	95	60.0	15	275.1	275.1	Yes	None
2	110	99	60.2	15	278.1	277.0	Yes	None
3	102	94	60.5	15	283.4	278.7	Yes	None
4	109	97	60.3	15	275.2	272.5	Yes	None
5	111	100	60.1	14	287.8	286.8	Yes	None
6	109	98	60.1	15	278.6	277.7	Yes	None

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 40 Wind Speed: 10 Direction: 3 19 NW

Comments _____

EMERGENCY BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ☒ GVWR ☐ LLVW
Dat 4-17-98 Driver: Lyle Observer:

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder ON OFF
  N/A ✓

Primary System Failure
60 mph Emergency Brake Stops

stop	Application Pressure (psi)		Speed (mph)	Decel (ft/sec^2)	Stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	full*		60.7	9	449.6	439.3	**Yes**	None
2	full		60.2	10	393.2	390.6	Yes	None
3	full		59.9	10	412.3	413.7	Yes	None
4	full		60.2	10	404.8	402.1	Yes	None
5	full		60.4	10	401.1	395.8	Yes	None
6	full		60.3	10	399.8	395.8	Yes	None

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 49 Wind Speed: 10 Direction: 301 NW
Comments * - pressures not available because application pressure was measured on the primary line which was vented for this case and therefore zero

EMERGENCY BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ❑ GVWR ❑ LLVW
Date: 4-17-98, 4-20-98 Driver: Lyle Observer: _____

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder. ON _____ OFF _____
  N/A ✓

Secondary System Failure
60 mph Emergency Brake Stops

stop	Application Pressure (psi)		Speed (mph)	Decel (ft/sec^2)	Stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	106	89	60.3	6	583.0	577.2	Yes	None
2	111	92	59.9	6	563.5	565.4	Yes	None
3	106	88	59.9	5	576.3	578.2	Yes	None
4	109	91	59.8	7	523.6	527.1	Yes	None
5	107	91	60.5	6	600.0	590.1	Yes	None
6	105	90	60.6	6	625.2	612.9	Yes	None

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 50-Fri; 38-Mon Wind Speed: 15-Fri; 0- 1 -Mon Direction: 307 NW-Fri; 210-Mon
Comments Stops 1 & 2 performed on Fri. 4/17/98
Stops 3-6 performed on Mon. 4/20/98

SERVICE BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ☐ GVWR ☐ LLVW
Date 4-20-98 Driver: Lyle Observer:

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder. ON OFF
  N/A ✓

60 mph Service Brake Stops

stop	Application Pressure (psi)		Speed (mph)	Decel (fpsps)	Stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	109	98	60.2	23	183.5	182.3	Yes	None
2	110	98	60.3	23	184.4	182.6	Yes	None
3	110	99	59.9	23	185.6	186.2	Yes	None
4	110	99	59.9	23	185.8	186.4	Yes	None
5	110	99	59.7	23	181.5	183.3	Yes	None
6	110	99	60.3	23	189.3	187.4	Yes	None

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 45 Wind Speed: 1 Direction: 238 SW

Comments

EMERGENCY BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ☐ GVWR ☒ LLVW
Date: 4-20-98 Driver: Lyle Observer: _____

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder. ON _____ OFF _____
  N/A ✓

Primary System Failure
60 mph Emergency Brake Stops

Stop	Application Pressure (psi)		Speed (mph)	Decel (ft/sec^2)	Stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	full*		60.2	10	337.7	335.5	Yes	Both rear
2	full		60.1	12	380.3	379.0	Yes	N/L
3	full		60.1	14	287.1	286.1	Yes	No. 3
4	full		60.3	14	300.2	297.2	Yes	No.3**
5	full		60.3	13	340.6	337.2	Yes	No.3**
6	full		60.2	12	337.5	335.3	Yes	No.3***

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 46 Wind Speed: 7 Direction: 182 S

Comments *- pressures not available because application pressure was measured on the primary line which was vented for this case and therefore zero ** Near end of stop *** Middle of stop

EMERGENCY BRAKE STOPPING TEST
Dry Concrete

Vehicle: 1996 Ford Louisville ☐ GVWR ☒ LLVW
Date: 4-20-98 Driver: Lyle Observer:

TEST SPECIFICATIONS:

- Check Tire Pressure
- 60 mph Service Brake Stops
- IBT 150 to 200 °F
- Clutch Depressed or Transmission in Neutral
- Brakes Can Be Modulated
- Vehicle in Center of Lane at Start
- Manually Controlled Retarder. ON OFF
  N/A ✓

Secondary System Failure
60 mph Emergency Brake Stops

stop	Application Pressure (psi)		Speed (mph)	Decel (ft/sec^2)	Stop Dist. (ft)	Corrected Stopping Distance per SAE J299	In 12 ft Lane	Wheel Lock-up Indication
	max	avg						
1	93	64	60.1	10	389.6	388.3	Yes	None
2	106	71	60.0	10	397.4	397.4	Yes	None
3	110	74	60.1	10	395.9	394.6	Yes	None
4	107	71	60.1	11	378.0	376.7	Yes	None
5	107	73	59.9	11	374.8	376.1	Yes	None
6	105	69	59.9	11	382.1	383.4	Yes	None

max pressure is the instantaneous peak pressure near beginning of braking, avg is the mean control-line pressure from time zero to the point at which speed reaches zero

Ambient Temp.: 48 Wind Speed: 5 Direction: 180 S

Comments

10.2 Appendix 2

FMVSS 105 - Navistar 4x2 Straight Truck
140" Wheelbase
Test Sequence

The remainder of the FMVSS 105 test procedure was not performed at VRTC for this vehicle.

FMVSS 105 - STABILITY & CONTROL TEST DATA SHEET

Vehicle: Navistar 4x2 Straight Truck ❑ GVWR ❑ LLVW
Date: 4-22-99 Driver: _____ Observer: Lyle

TEST SPECIFICATIONS:

- Check Tire Pressure
- Max. Drive-Through Speed (nearest whole mph): 34
- 75% of Max. Drive-Through Speed (nearest whole mph): 26
- Braking Runs at 30 mph or 75% Max. Drive-Through Speed: 26
- IBT 150 to 200 °F
- Clutch Depress or Transmission in Neutral
- Full Brake Application
- Vehicle Within Lane at Start
- Manually Controlled Retarder ON _____ OFF ✓
  N/A _____

Maximum Drive Through Speed: 34 mph 75% of Max Drive Through Speed: 26 mph

stop No.	Speed (mph)	Approx. Dist. Out of Lane (ft)	No. Markers Hit	Comments
1	26.0	0	0	
2	26.			
3	2626.0	00	00	
4	26.0	0	0	

Ambient Temp.: _____ Wind Speed: _____ Direction: _____

Comments Max Required Brake Through Speed - 26 mph
Max Brake Through Speed - 35 mph

FMVSS 105 — STABILITY & CONTROL TEST DATA SHEET

Vehicle: Navistar 4x2 Straight Truck ☐ GVWR ☐ LLVW
Date: 4-22-99 Driver: _____ Observer: Lyle

TEST SPECIFICATIONS:

- Check Tire Pressure
- Max. Drive-Through Speed (nearest whole mph): 35
- 75% of Max. Drive-Through Speed (nearest whole mph): 26
- Braking Runs at 30 mph or 75% Max. Drive-Through Speed: 26
- IBT 150 to 200 °F
- Clutch Depress or Transmission in Neutral
- Full Brake Application
- Vehicle Within Lane at Start
- Manually Controlled Retarder ON _____ OFF ✓ N/A _____

Maximum Drive Through Speed: 35 mph 75% of Max Drive Through Speed: 26 mph

stop No.	Speed (mph)	Approx. Dist. Out of Lane (ft)	No. Markers Hit	Comments
1	26.0	0	0	
2	26.0	0	0	
3	26.0	0	0	
4	26.0	0	0	

Ambient Temp. : _____ Wind Speed: 19-21 mph Direction: 194°

Comments Max Required Brake Through Speed - 26 mph
Max Brake Through Speed - 33mph

10.3 APPENDIX 3

10.3.1 - Roller Dynamometer Brake Force Measurement

A Hans Hermann BM Roller Dynamometer was used to measure the brake retardation force produced by each test vehicle. Individual wheel brake forces were compared to the input pedal force on hydraulic braked buses, and to the treadle applied control air pressure on pneumatic braked trucks. Individual graphs of the dynamometer measured braking forces vs. the respective inputs are located in section 10.3.2. The dynamometer data provides a benchmark, for the VRTC lab, to indicate the brake force at each wheel and the balance of the whole braking system. If the vehicle does not respond as expected during a test on the track, a quick retest on the dynamometer often aids in diagnostics. This is not a test required by FMVSS No. 121.

The BM Roller Dynamometer used two 24-hp (18-kW) electric motors to individually drive both the left and right wheels of the selected axle simultaneously at 2.2 mph (3.5 kph). While the driver applied an increasing force to the brake pedal to activate the brakes over the whole service range, a pedal force transducer or a treadle pressure transducer recorded the input effort, and load cells in the dynamometer measured the axle weight and the generated braking forces with respect to time. Plots were then generated to reflect the output brake force for the given input effort.

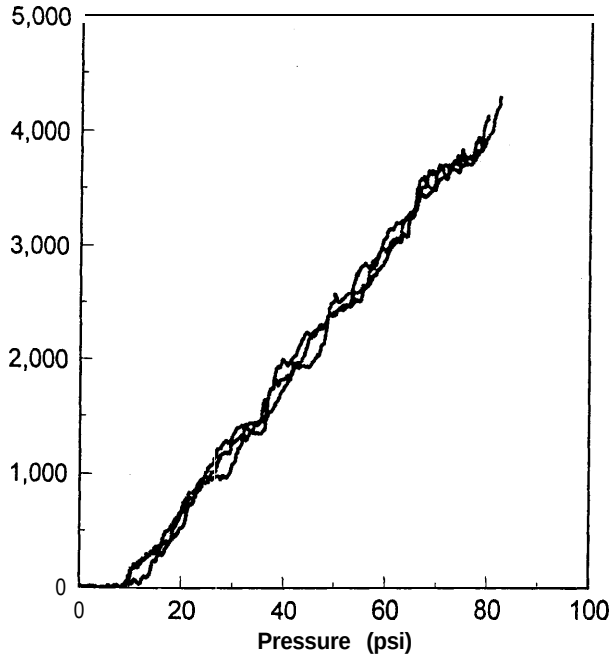
The roller dynamometer test was normally run after the 500 mile initial brake burnish cycle while the test unit was still loaded to GVWR. There was negligible difference in output between drum brakes at room temperature and ones that were slightly warmed. Typically, the drum brakes were dynamometer tested at room temperature. However, the hydraulic braked vehicles were equipped with disc brakes, and more uniform results were obtained with slightly warmed brakes. Typically, a warming cycle for the disc brakes consisted of driving the vehicle on the track, and performing four to six snubs, from 40 mph to 20 mph, at a deceleration rate of 10 feet per second per second (~0.31g).

10.3.2 - Roller Dynamometer - Graphs Of Brake Force Output Vs. Input

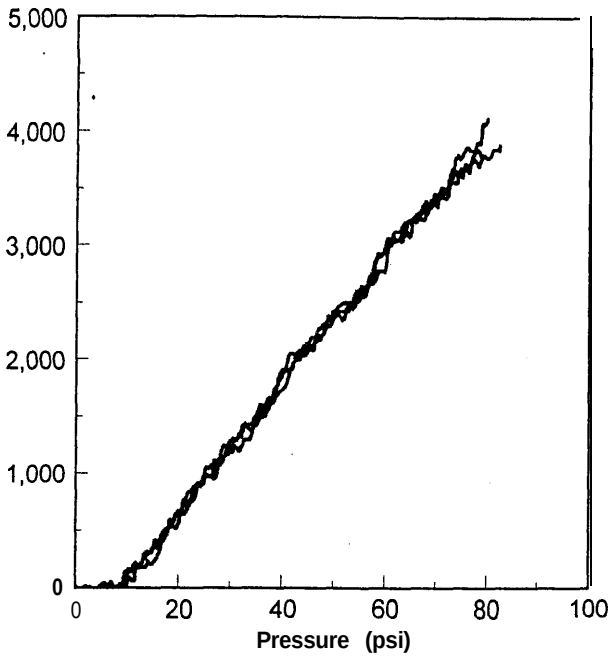
Ford HN80 4x2 Straight Truck

148" WB

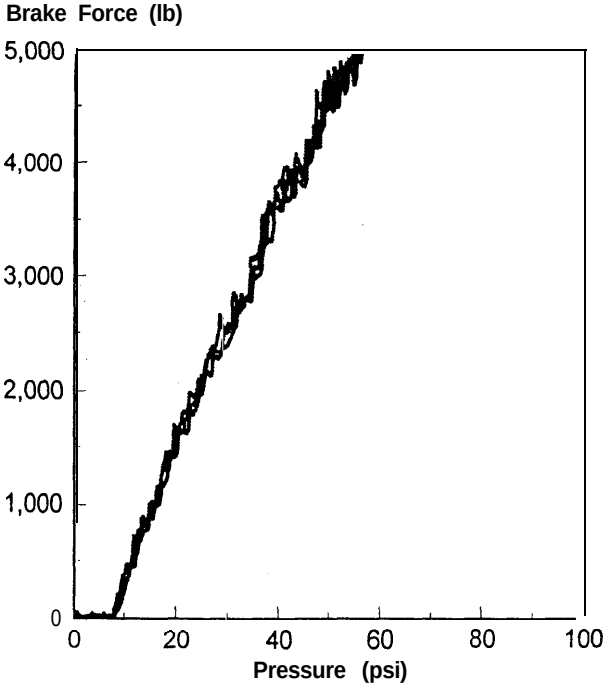
Left Front



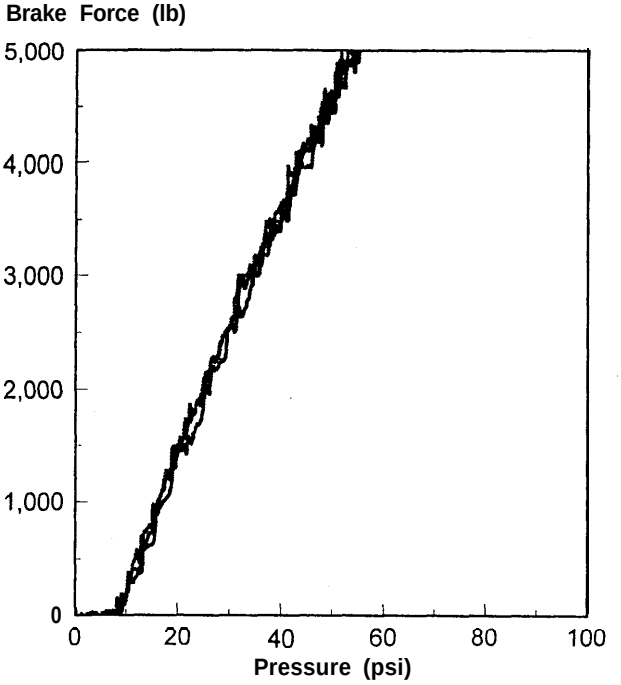
Right Front



Left Rear



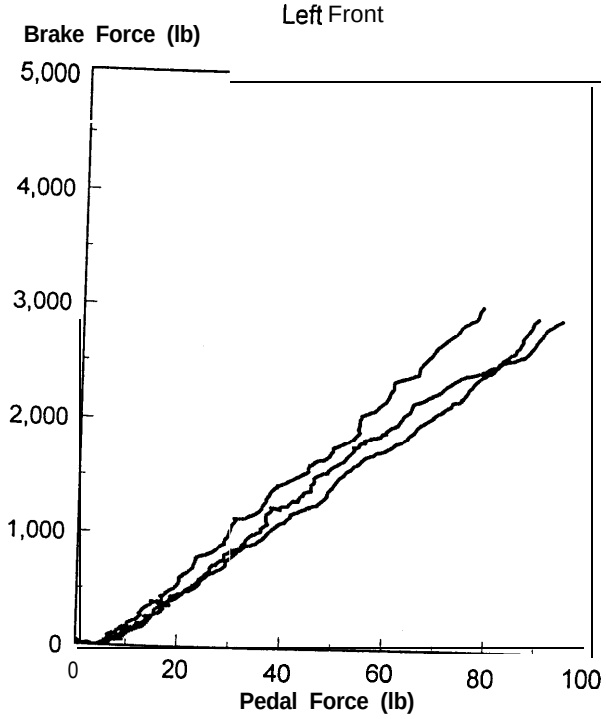
Right Rear



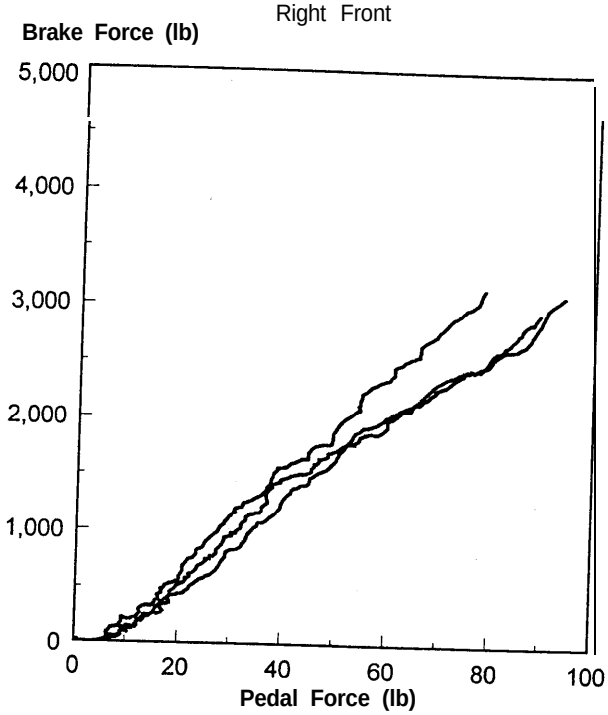
Navistar 4x2 Straight Truck

140" WB Hydraulic Brakes

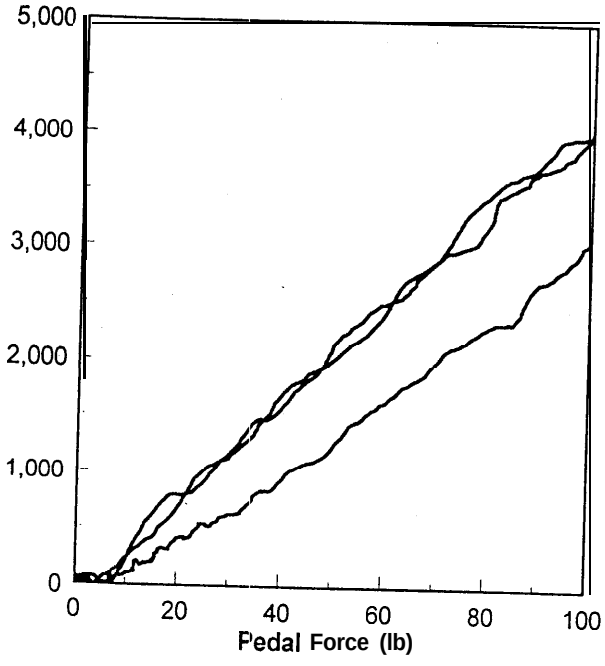
Left Front



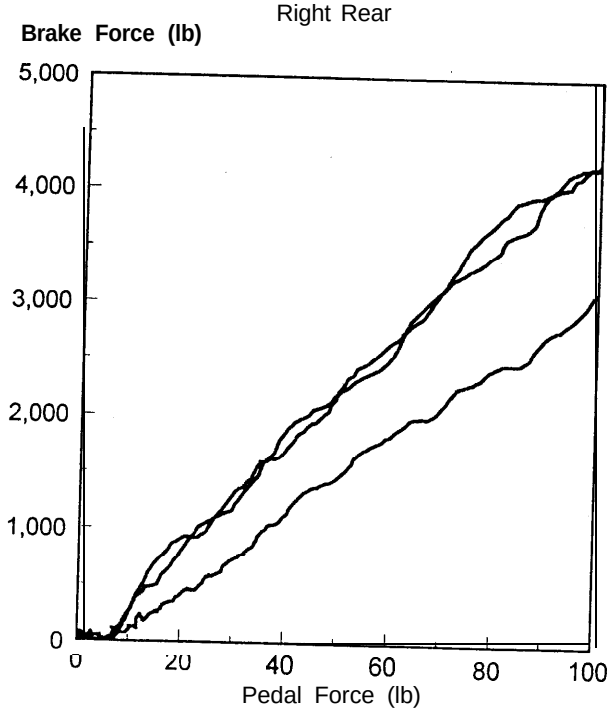
Right Front



Left Rear



Right Rear



10.4 Appendix 4

10.4.1 - Index to Vehicle Information Sheets and Photographs A10-1

10.4.2 - Vehicle Information Sheets

10.4.3 - Pictures of Vehicles, Components, & Instrumentation

Key to pictures: GAWR = Gross Axle Weight Rating; GVWR = Gross Vehicle Weight Rating

VEHICLE INFORMATION SHEET

Vehicl 1996 Ford Louisville
Test No.: H Test Date(s): 4/16-20/99
Test Facility and Location: Transportation Research Center East Liberty Ohio
Year, Make, and Model: 1996 Ford Louisville (Tractor tested as a straight truck)
VIN or Unit No.: 1FDYS80E4VVA09765
GAWR, lb: 1st Axle 12,000 2nd Axle 23,000 3rd Axle NA GVWR 35,000
Center of Gravity Height, in:

- Truck, unladen (above ground)(in):
- Truck, laden (above ground)(in):
- Truck Ballast (above top of frame): 25.5 in

Wheelbase, in: 148
Curb Weight -Distribution, lb:
Unladen: 1st Axle: 7,740 2nd Axle: 6,300 Total: 14,040
Laden: 1st Axle: 11,850 2nd Axle: 22,990 Total: 34,840
Retarder(s) Type(s): No
Aerodynamic Treatments: (Yes/No) (Attach Photo): No

BRAKES:

Axles:	Type[1]	Size, in	Make	Lining (Edge Code)
1	FGHT-3010-BB			
2	RS23160DNFNN87			
3	NA	NA	NA	NA

Brake Drum/Rotor

Axles:	Type[2]	Make	Dust Shields Installed?
1	Drum 15.0" x 4" Wide	Budd 203-8804	No
2	Drum 16.5" x 7" Wide		No
3	NA	NA	NA

ACTUATION DETAILS:

	Actuators		Slack Adjusters		
Axle	Make	Type[3]	Length or Wedge angle	Manufacturer	Cam Rotation[4]
1	Midland	20	5.5"	Haldex	
2	Maxi-Brake	30-30	5.5"	Haldex	
3	NA	NA	NA	NA	

VEHICLE INFORMATION SHEET
(Continued)

Vehicle: 1996 Ford Louisville

TIRES:

Axles:	Pressure (psi)	Size	Make	Model	Static Loaded Radius (in) Measured	DataBook
1	105	11R22.5	Goodyear	Unisteel G159	19.5"	19.4"
2	105	11R22.5	Goodyear	Unisteel G167A	19.8"	19.7"
3	NA	NA	NA	NA	NA	NA

ABS: Manufacturer: i x Model: N/A Configuration: 4x2

FRONT **SUSPENSION:**

Type: Spring Make: Model:

REAR **SUSPENSION:**

Type: Spring Make: Model:
Axle Spread, in(in): Overall Width (SAE J693):

AIR **SYSTEM:**

Compressor Capacity ccm(cfm): Cut-out kPa(psi): Cut-in kPa(psi):
Crack Pressure Ratings(psi)[5]:
1st Axle: 2nd Axle:
3rd Axle: Treadle Valve:
Bobtail Proportioning: ❑ Front Axle Limiting:
Air Dryer: ❑ Air Compounding:
Spring Brake Inversion Valve: ❑ Number of Brakes Controlled:
Specifics Regarding Air Brake System Components:

AIR TANK VOLUMES 1 (cu.in.):

Supply: Primary: Secondary:
Auxiliary:- Isolated From Service? ❑

SPECIAL CONDITIONS:

Special conditions or equipment which might affect brake performance:

[1] Cam, disc, wedge, etc.
[2] Cast or composite drum, vented or non-vented rotor, etc.
[3] Size and diaphragm or piston
[4] Same or opposite to forward wheel rotation
[5] Relative to rear axle(s) centerline (include sketch if necessary)

VEHICLE INFORMATION SHEET

Vehicl 1998 Navistar 4900 4x2 Straight Truck
Test No.: 1 Test Date(s): 4/22/99
Test Facility and Location: Transportation Research Center East Liberty Ohio
Year, Make, and Model: 1998 Navistar 4900 4x2
VIN or Unit No.: 1HTSDADP7WH594514
GAWR, lb: 1st Axle 8,000 2nd Axle 15,500 3rd Axle NA GVWR 23,500
Center of Gravity Height, in:
*Truck, unladen (above ground)(in): 40 in NO load frame installed (Navistar Estimate)
*Truck, laden (above ground)(in): 65 in (Navistar Estimate)
*Truck Ballast (above top of frame): 50 in
Wheelbase, in: 140
Curb Weight Distribution, lb:
Unladen: 1st Axle: 7,070 2nd Axle: 7,500 Total: 14,570
Laden: 1st Axle: 8,070 2nd Axle: 15,160 Total: 23,230
Retarder(s) Type(s):
Aerodynamic Treatments: (Yes/No) (Attach Photo): No

BRAKES:

Axles:	Type[1]	Size, in	Make	Lining (Edge Code)
1				
2				
3	NA	NA	NA	NA

Brake Drum/Rotor

Axles:	Type[2]	Make	Dust Shields Installed?
1	Vented Rotor		
2	Vented Rotor		
3	NA	NA	NA

ACTUATION DETAILS:

	Actuators		Slack Adjusters		
Axles:	Make	Type[3]	Length or Wedge angle	Manufacturer	Cam Rotation[4]
1	Hydraulic				
2	Hydraulic				
3	NA	NA	NA	NA	

Calipers: Dual 66 mm Front and Rear

VEHICLE INFORMATION SHEET
(Continued)

Vehicle: 1998 Navistar 4900 4x2 Straight Truck

TIRES:

Axles:	Pressure (psi)	Size	Ma k	Model	Static Loaded Radius (in) Measured	DataBook
1	- -	1200x22.5	Goodyear	Unisteel G159		
2	- -	1200x22.5	Goodyear	Unisteel G 159		
3	NA	NA	NA	NA	NA	NA

ABS: Manufacturer: Bendix Model: Hydromax Configuration:

FRONT SUSPENSION:

Type: Spring Make: Model:

REAR SUSPENSION:

Type: Spring; Make: Model:
Axle Spread, m(in): Overall Width (SAE J693):

AIR SYSTEM:

Compressor Capacity ccm(cfm): Cut-out kPa(psi): Cut-in kPa(psi):
Crack Pressure Ratings(psi)[5]:
1st Axle: NA 2nd Axle: NA
3rd Axle: NA Treadle Valve: NA
Bobtail Proportioning: □ NA Front Axle Limiting: NA
Air Dryer: □ NA Air Compounding: NA
Spring Brake Inversion Valve: □ Number of Brakes Controlled: NA
Specifics Regarding Air Brake System Components: NA

AIR TANK VOLUMES 1 (cu.in.):

Supply: NA Primary: NA Secondary: NA
Auxiliary:- NA Isolated From Service? □

SPECIAL CONDITIONS:

Special conditions or equipment which might affect brake performance:
Bendix Hydromax Booster System , International 275 HP V8, Spicer 7-Speed Manual Transmission

[1] Cam, disc, wedge, etc.
[2] Cast or composite drum, vented or non-vented rotor, etc.
[3] Size and diaphragm or piston
[4] Same or opposite to forward wheel rotation
[5] Relative to rear axle(s) centerline (include sketch if necessary)

FIGURE 10.1 - Ford 4x2 Straight Truck - Unit H, FMVSS No. 121
Spring Suspension, Air Brakes, 148" Wheelbase, GAWR Front 12,000, GAWR Rear 23,000

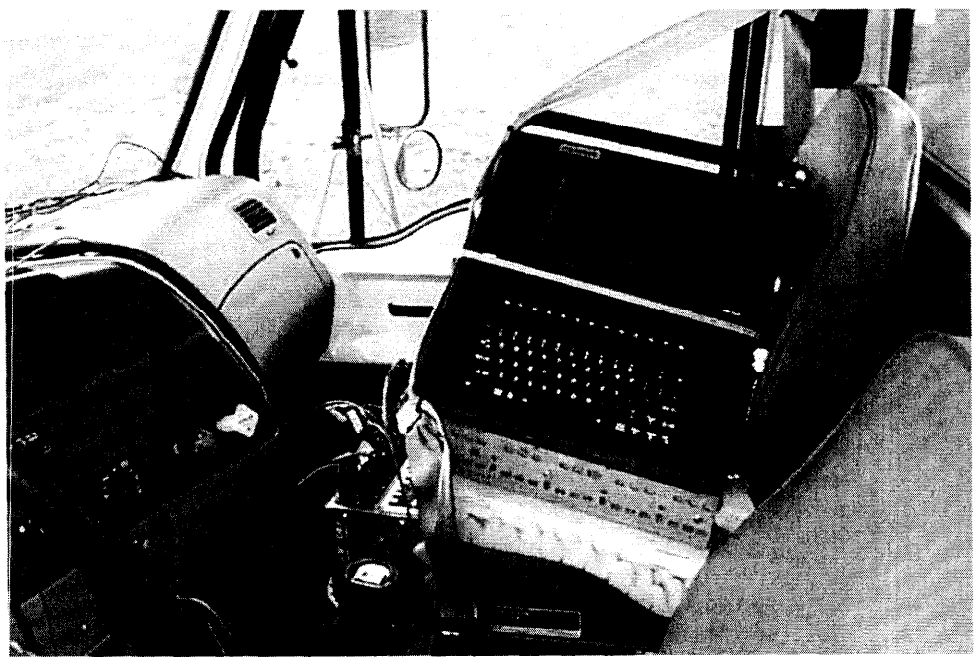


FIGURE 10.2 - Ford 4x2 Straight Truck - Unit H, FMVSS No. 121
Data Acquisition System cushioned by right seat and padding, secured by seat belt and nylon web seat bottom strap

FIGURE 10.3 - Ford 4x2 Straight Truck - Unit H, FMVSS No. 121
Driver Feedback Devices: Labeco Performance Monitor for Initial Speed and Stopping Distance, Analog Dial Gauge for Control Pressure, and Fluke Digital Thermometer for Monitoring Brake Lining Temperatures

FIGURE 10.4 - Navistar 4x2 Straight Truck - Unit I, FMVSS No. 105
Spring Suspension, Hydraulic Brakes, 140" Wheelbase, GAWR Front 8,000, GAWR Rear 15,500
Truck with Load Frame - Empty Condition

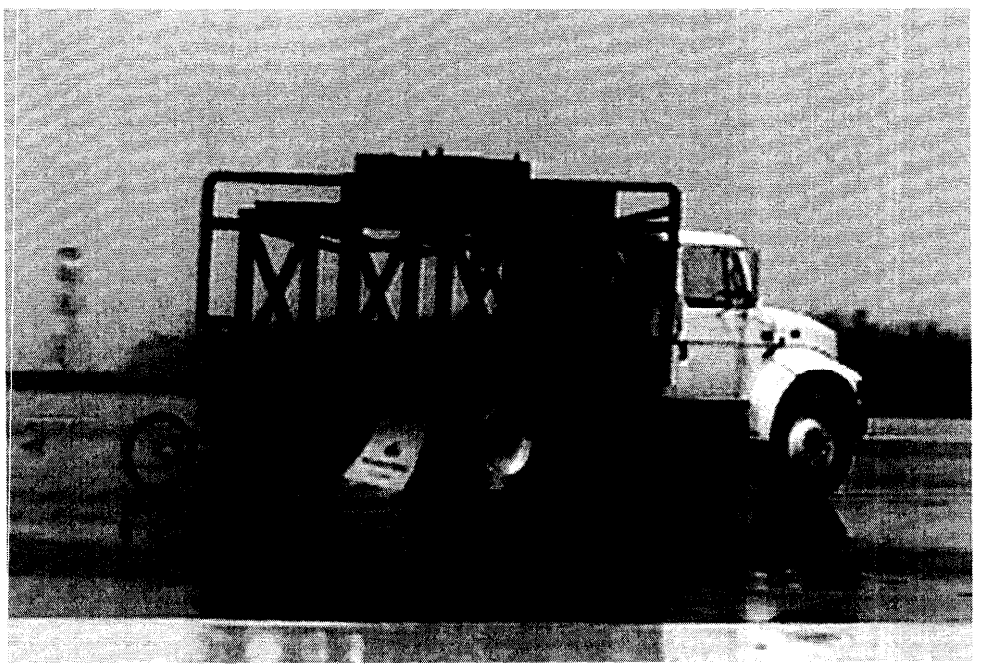


FIGURE 10.5 - Navistar 4x2 Straight Truck - Unit I, FMVSS No. 105
Spring Suspension, Hydraulic Brakes, 140" Wheelbase, GAWR Front 8,000, GAWR Rear 15,500
Fully Loaded Condition